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AUTHOR	Fortner, Rosanne W.
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ABSTRACT

This paper explains the structure of the International Organization of Science and Technology Education (IOSTE) and the relevance of science and technology education. To support the environment, education should integrate the environment into the curriculum, and the information should be delivered as a system. Earth Systems Education (ESE) is a structured curriculum based on the integrated approach and uses Earth as the focal point of the curriculum. (YDS)

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Science and Technology Education – Shaping the Environment of the Future

Rosanne W. Fortner, The Ohio State University, USA,
fortner.2@osu.edu

It is a sign of great foresight and wisdom that led the IOSTE conference organizers to include a sub-theme about Environmental Issues in a conference on Science and Technology Education. While the subject area stands out as very different from the other sub-themes, a bit of thought is all that is required to see the connections. The environment is being shaped each day by human understanding (or misunderstanding) of science, by applications of technology (or mis–applications), and by the way young people are taught to connect, apply, and deal with the effects of that science and technology.

As educators, our responsibility is to help learners prepare for their future, and in so doing we configure our own future as well. Science is the fastest changing curriculum area for schools. A test we develop today to evaluate student knowledge of science may be obsolete tomorrow as we learn more, connect more disciplines, and examine the subtle ways that our understanding of science is changing. The textbook in that heavy student backpack today is lacking in current data and insights; its examples are global but students have no tools for seeing local applications of them. The Internet as a curriculum supplement provides much science information, but we lack effective ways of selecting materials and using that resource. Internet technology seems somehow separate from our realities, and while it has potential to connect us for conversation worldwide, it may divide our cultures because of inequality of information access.

In the world outside the classroom, it is technology that is the fastest changing aspect of life. There is mounting evidence that our goal is to make our communication technologies faster, better, and more compact (a Watchman, pocket–size cellular phone, microsurgery). For other technologies, faster, better and larger size may be the goal (the Concord, the supercollider, the Ford Expedition). Technology goals in the U.S. drive research in universities and industry, and therefore they restrict attention to certain types of development, starving other deserving research for the lack of funds. Ohio State designated all its discretionary research funds this year to study biotechnology, nanotechnology, and information technology. Apparently no one saw the value of looking at big picture research that might involve ecosystems, atmospheric changes, and long–term trends in species loss.

What will we discover when we do decide to look at the big picture of the environ-

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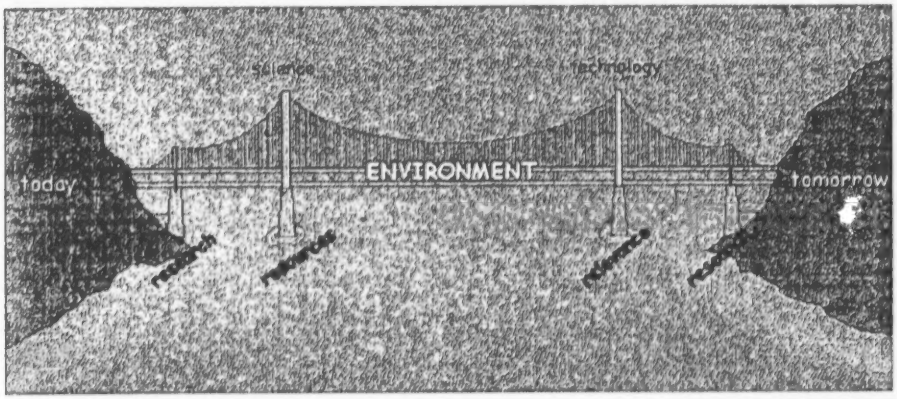
ment? Speedy development is not always accompanied by foresight. We build, then we assess. In the process we have embarked on what could be some interesting one-time experiments! When we discover what effects our technological progress has brought, will there be time to avert the impacts? Can the Mediterranean survive the changes brought by the introduced *Caulerpa* seaweed; will atmospheric changes bring us a greenhouse or an ice age; will future wars be fought over water supplies? What kind of environment are we shaping for the children to inherit?

The time has come to use our science and technology, through deliberate and well-planned education, to assure that the future we are building is one that is sustainable and peaceful. The tools to do that are available, but the motivation to use them has been lacking. Teachers are charged with the task of educating the next generation, so changes in schools may be the key to changes in the environment.

How does the environment relate to the IOSTE conference components?

Imagine the parts of the conference as pieces of a bridge that is being built. The bridge is the Environment, and it connects us in Today's world to those who will inherit Tomorrow's world. Before the span can be erected, it must have strong support, provided here by the sub-themes.



- **Resources for instruction**. While textbooks have their place in instruction, they must not be the only resource used. Lectures and reading are shown to result in students learning only about 30% of what is presented. "I hear and I forget. I see and I remember. I do and I understand!" These words have been a motivation for science educators around the world for many years. The words mean that far greater amounts of time must be spent *doing* science, experiencing the interconnections of the Earth system, constructing learning by manipulating tools and evaluating cause–and–effect. The student who can answer all the TIMSS questions correctly but believes the beach litter comes only from the sea has not been adequately prepared for the environmental future.

- **Relevant teaching**. Because of the reliance on textbooks, often produced in other areas and trying to tell everything in a small space, many students have trouble relating global ideas to what they see around them. Schools should make use of the people, places, and things near the school for their instructional potential. There is no cost for bringing in guests from the community, walking around the school yard to collect environmental measurements, or assembling data on local changes over time. There is a large cost to *not* doing so, as students lose connection to their environment while they gain access to whoever will call them on their cell phones and instant messagers. Schools need curriculum *activities* that encourage local learning, and assessment needs to look at more than recitation of exact answers. Local projects offer much for relevant learning, but even everyday classroom interactions with small groups of students will assist learners in becoming cooperators in their own education.
- **Research** has been done on many of the aspects of education we seek to try. Professional journals provide activities and assessment ideas, and the research articles can offer much to the practicing teacher. As in the world at large, where "those who do not know history are condemned to repeat it", educators who do not expand their own learning through professional readings and courses may get through the school day but they never contribute to the growth of their discipline. Improvement of education requires that instructional leaders (teachers) become lifelong learners themselves. Not only does this improve the classroom, but it also renews teacher enthusiasm and contributes to positive role modeling. Both theoretical and applied action research are needed for our growth.

Thus we lay the bridge of environment across these important pillars, and it reaches from today to tomorrow. Then we build its superstructure to have even greater strength: the towers are the science and technology that can either serve the environment or threaten its integrity. To make those towers as powerful as possible requires more of that lifelong learning. Teachers need to know not only their own science discipline, but the full fabric of interdisciplinary sciences. Too many facts? If that is how science is being learned, of course adding disciplinary knowledge will add too many facts. Science instead needs to be studied as a system, with processes common to all disciplines and connections that cannot be ignored.

How important are environmental issues to teachers and students?

Research from many countries supports the idea that teachers and students value the environment and want to protect it. For example the specific issues tested among Cyprus teachers of secondary science are shown in Figure 1. A total of 110 useable responses were returned from the population of 167 natural science teachers, for a response rate of 61%. The respondents included 53 males and 44 females, with an average of 18 years' teaching experience. Bars show the teachers' responses to (a) How important is the issue for students in your school to know about? (b) How much do you know about the topic? (c) How much do you teach about the topic?

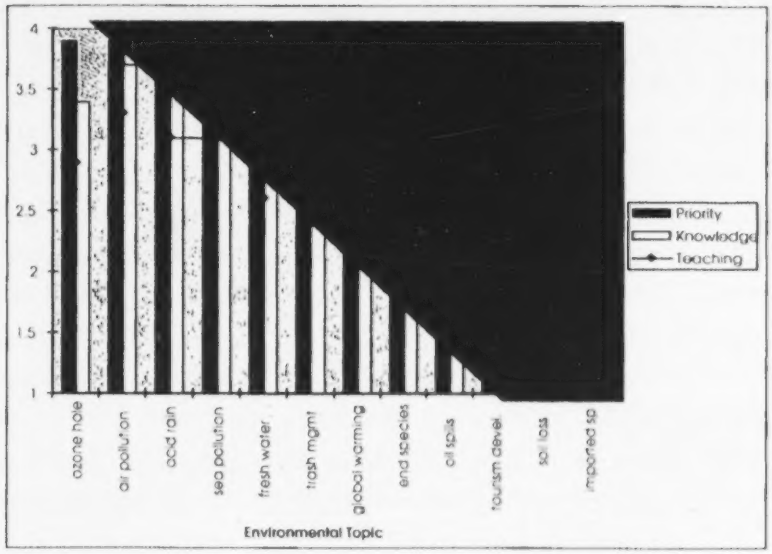


Fig. 1. Teacher Priorities, knowledge and Teaching of Environment Topics.

Similar questions are being posed to preservice teachers and to Lyceum students for comparison across the generations. What does the information do for our education planning? In this early analysis it appears that some critical subject matter may not be reaching students in Cyprus. Imported species are common on the island, and though some may have negative impacts there is no agricultural inspection at Customs, and people routinely bring favorite plants from other countries for cultivation in Cyprus.

Fresh water availability is a serious issue for the country. Water for city homes may be rationed in drier seasons. It appears that the concept of consumptive versus nonconsumptive uses of water is not being taught. Agriculture (a consumptive use that pulls water out of the hydrologic cycle for long periods) claims 78% of the island's water use, and the popular citrus and peanuts (non-native crops) are the biggest consumers. Combining the science of hydrological processes with the social applications of water and conservation would provide excellent instructional opportunities for data analysis and decision–making. Since water management in Cyprus relies on reservoirs, desalination, and some recycling of waste water, incorporation of these technologies into discussions in science classes would use local resources, make the learning relevant, and offer students the opportunity to develop research skills in a real–world context. The environmental bridge would be built for that topic.

In the U.S. many sections of the country are water–rich, and research has focused on how teachers use that resource to make their instruction locally relevant. A study in the Great Lakes region found that teachers ranked the priority for water issues as 1)

water quality, 2) personal responsibility for the environment, 3) toxic chemicals, and 4) water uses and conservation. They indicate a wide range of knowledge about the 22 topics tested, but sometimes choose not to teach a topic because it is not relevant to their curriculum, or it does not appear on the statewide test their students must take. The same is true in most topical assessments of this type: teachers adhere to the curriculum content and do not often diverge. Lack of time is an issue, as is the testing system that does not include the topic. Unfortunately a systems approach for interdisciplinary science has not made sufficient advances to support teachers in a choice to add environmental material to the curriculum.

How much do people know about the science of the environment?

Research indicates teachers place a high priority on climate change as a topic their students should know, but report their own knowledge as inadequate for teaching it. Students (and some teachers) seem unable to distinguish among related environmental issues, and treat general "environmentally friendly" behavior as affecting all issues. The curricular fit of global climate change, for instance, is best in Earth systems oriented classrooms, but opportunities exist across the curriculum. Instructional materials are available, though these may not address misconceptions. Some interest groups oppose human–mediated climate change as a curriculum topic, for the same reasons they oppose public action on the problem.

Research indicates that there are some common misconceptions about environment and its issues. Many people, for instance, group all environmental issues into one mental cluster. They apparently see all issues as having the same causes, and therefore the same actions can reduce the problems. In very basic terms, environmental issues = "pollution", and the best thing to do about the issues is to recycle. We have clearly not tapped the potential for individual environmental actions, nor taught enough about the range of problems threatening the global environment.

In the case of climate change, for example, secondary school students (ages 11 and up) know that global climate change will be associated with changes in weather patterns, and they can basically describe how the greenhouse effect works to increase temperatures in the lower atmosphere. However, these students, as well as college students and preservice teachers, frequently hold incorrect perceptions about Earth system relationships as well as how human activities impact those systems. Results regarding misconceptions are remarkably similar across education levels. The most common misconceptions are:

- Inflated estimates of temperature change compared to IPCC estimates
- Confusion between CFCs, the ozone hole, and climate change (ozone layer depletion causes climate change; stop using aerosols to prevent global warming)
- Perceived evidence — warmer weather (reportedly they could personally sense rising climatic temperatures or changes in long–term weather)
- Confusing weather and climate

Teachers and global climate change were the subjects of other studies with different results to offer. A group of teachers in an inservice program about climate change appeared to feel strongly that their own behavior serves as a model for their students. Interview and journal data demonstrated they were conscious of showing best practice regarding their personal responsibility for global climate change. The teachers appeared to believe that if teachers show active interest and involvement in taking citizenship action, then students are more likely to do the same. This is a positive scenario that we hope is repeated in other teachers.

Is environment a key to sustainability and peace?

Sustainability has many meanings, but what it means to teachers may be most important here. A group of student teachers in Exeter, UK, provided some useful and insightful definitions. Each comes from a different student:

- "Sustainability involves an awareness of what is happening to the planet and an effort to protect and care for the Earth. It includes advances in technology and an understanding of the implications of these for the Earth".
- "Sustainability in terms of technological 'progress' is that which does not detract from, diminish or destroy what exists in the natural world".
- "Sustainability is the need for a balance between technological development for a better life for humans and the needs of the environment. It implies living within the Earth's carrying capacity and creating a global alliance".
- "Sustainability is the advance of technology in harmony with caring for the environment on a global scale".

Notice how frequently Technology is mentioned or implied within the definitions. These young teachers recognize that some environmental threats are linked to human actions as we develop our lifestyles. If this is true, there is probably a different view of environmental sustainability in developed countries and those that are struggling to develop technology. Some surprising revelations may be in store here. When the world was preparing for the Earth Summit in 1992, the Gallup organization did an international survey in 24 countries to determine how people felt about the health of the environment. In an open–ended question, a majority of people in 2/3 of the countries listed environment as one of the top three problems. Only economic issues were more prevalent in the lists. Even people in the poorer regions like Mexico, India and Chile ranked environment as a top issue.

Who is responsible for the problems? Across the 24 nations surveyed, respondents were most likely to blame business and industry as the major contributor to their own nation's problems. Next most likely causes were technology and wasteful practices, followed by lack of citizen education and poor government. Most people felt that the government had the primary responsibility for dealing with environmental problems, but they did acknowledge the importance of individuals and group actions as the second or third choice. In the lower-income nations, citizens are more likely to be seen as having

major responsibility. This is an interesting finding, and it shows how closely survival in poor countries is tied to environmental quality. According to psychologists, most individuals prioritize their activities according to Maslow's hierarchy, taking care of personal survival needs (biological requirements, safety) first and holding the optional desires (esteem, involvement in causes) until primary needs are met. Environmental quality (protection of water supplies, for example) may be a determiner of biological survival where technology is not advanced, thus may be considered a primary need. There is also cause for caution in assessing technology's effects, as it is apparent that technology (defined by Gallup as "the way products are made uses too many resources and creates too much pollution"), while it may assist survival in some cases, is seen by many as a threat to the environment.

Peace is another issue. The optimists among us find great reason to see that cooperation for environmental quality could be a key to peace among nations. It only takes a satellite image of Mt. Pinatubo's volcanic ash plume, or a dusting of red African sand on our cars to remind us that environmental issues do not respect political boundaries. Those downwind of Chernobyl or the Iraqi oil fires, and those at the eastern end of the Mediterranean's cu-de-sac for beach debris, know that what is produced in one country may create problems for others. We all live downstream, and we all contribute to what goes into that stream. Likewise, when organisms in the flow of air or water are moving from place to place, their protection must come from all of us to guard the places where they come ashore to deposit their eggs , where they spend the other seasons, or where they stop over in migration. Care of sea turtles, migratory birds, whales, and monarch butterflies is a global responsibility. Nations that work together for the environment may just find that they can work together on other aspects of life as well! UNESCO, UNEP, the Global Environment Facility and other organizations are based on this premise. Is it important to school science and technology? If we value relevance in science teaching, and we are committed to development of literate citizens for a technological world, the answer must be "yes".

Research in the Greek and Turkish communities of Cyprus for Earth Day 1999 involved environmental professionals meeting on the topic of "Earth Learning, Earth Living". The attendees were asked to examine environmental issues on a list developed with the assistance of natural resource professionals in both communities. Some items on the list were issues only in one sector of the island, but the respondents rated all issues for their Significance, Certainty, Tangibility and Complexity. They also indicated how willing they were to act for the solution of the issues. A comparison of the Issue Significance responses and Willingness to Act, by community, is shown as Figure 2. While it is not possible from this research to determine whether Cypriots from all parts of the island would be willing to work *together* on environmental concerns, it is clear that the environmental professionals see the issues as very significant and are willing to take personal action on most. Events such as the "Earth learning, Earth living" conference help to make the politically separated peoples aware of their commonalities and their mutual dedication to environmental quality.

Peace using the environment as a context has important implications for students. All over the world, students have been joining each other in computer networks related to environmental monitoring, such as the GLOBE program (Global Learning and Observations to Benefit the Environment) which involves almost 200 countries. They know it is possible and desirable to communicate and share across cultures, and they are growing up with the expectation of being able to converse on an equal basis with their peers anywhere in the world. The journal *Technology & Learning* reported in January 2001 that the percentage of students accessing the internet from school is 78% in Sweden (the highest measured), 63% in Taiwan, 59% in the US and UK, 28% in Italy and Japan, 25% in France and Germany, and even 13% in urban sections of China. Students are literate in the technologies closest to them, and they expect this tool to put them in touch with people and information around the world. What they know of international warfare and intercultural conflict they learn from people who claim to be grown–ups. Just as the students become our mentors when we need computer assistance, they could teach us some things about relating to others around the world and sharing commitment to its environment.

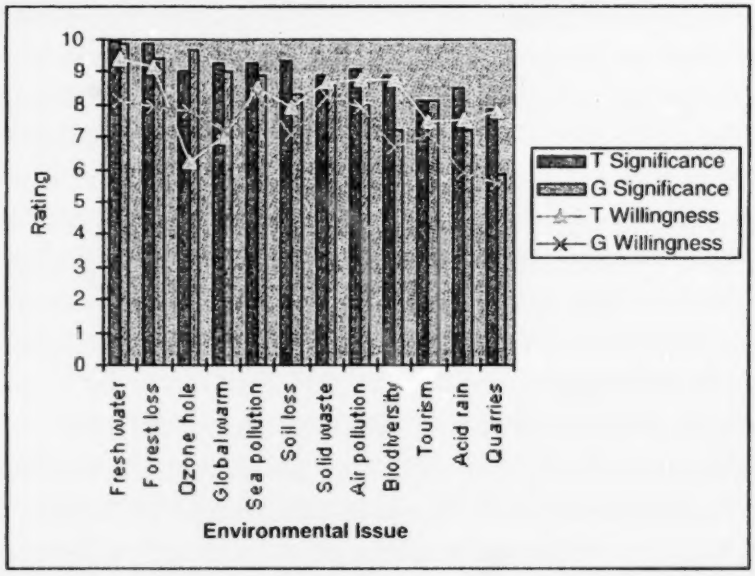


Fig. 2. Comparison of Significance ratings and Willingness to Act for selected Environmental Issues in Greek and Turkish Cypriot communities.

In autumn 2000 the Hellenic Marine Environment Protection Association (HELMEPA) published in its NEA newsletter a report of the children's Board of HELMEPA JUNIOR, a group aged 6–13 from nine regions of Greece that represents

3500 children nationally. The group drafted a resolution they hoped would be heard by the powerful on Earth. It included these lines:

> "Our everyday indifference, apathy and tolerance [of pollution] is nothing more than our complicity to the drama of the environment. Environmental Awareness is not enough but pressure from all of us to the grown–ups and to the Powerful on Earth is needed so that wishes and big words turn into ACTIONS".

How can we support the environment with what is learned in this conference?

"Where there is the will, there is a way!" In other words, if we are determined to do something, we will find a way to do it. Commitment to the principle of education that includes environment is the primary assumption, and the goal we wish to establish in our classrooms if the bridge to tomorrow is to be built. To use the wealth of information delivered here on science, technology and environment education, we must learn to think like a system. In a system, everything is connected to everything else, and education sometimes has difficulty relaying that concept to students. The tradition of educating teachers in discrete disciplines, the practice of changing classes, the separation of home from school, all create separate divisions in our thinking and enforce those divisions over space and time. Science ends for students when they leave our classroom. The teaching of biology is not intentionally integrated with the teaching of physics. School lessons don't have to be applied in real life. The problems are multitude.

If we approach learning about science, technology and the environment as a system, integrated among themselves and with the other subject areas in the school, we begin to find reasons to work together on lesson plans. We admit that we don't know everything about the environment (yet), or technology (ever), so we find colleagues who do know things, and we learn from each other. We share lesson plans, develop collective field trips and outdoor laboratories to make the learning relevant, examine new subject areas that cross over several sciences and perhaps add creative writing or role–playing about making decisions. Being part of a system frees the teacher to be creative and to continue building personal knowledge as well as teaching it to others.

There is a curriculum restructure effort in progress in many countries called *Earth Systems Education* (ESE). Designed for preschool through college, but focused mainly on secondary science classrooms, ESE makes Earth the focus of the curriculum. Students are taught how their surroundings here and now relate to the greater scales of time and space that characterize global topics. They work in cooperative groups to explore their environment using real data and precise observations, outdoors, on line, in labs and classrooms. In many cases environmental issues or natural systems are used as the subject matter for learning, because no part of the environment comprises just one discipline. ESE is taught through student investigations driven by interesting questions to be explored, so the sciences are learned on a need–to–know basis rather than as chapters in a given order in an encyclopedic textbook. It fosters appreciation of Earth's beauty and value, which rarely happens in traditional science classrooms. Even if we were

studying the local rocks, their primary science of geology is subject to the changes brought by wind, sun and water. Rocks are broken down by plant and animal actions, and in turn support more growth and support for those organisms. Rocks are used in technology for buildings and carved monuments. Their strength and position determine their uses and dictate how they can support human-made structures and activities. They are woven into the legends that are our heritage. This is an example of how one common topic becomes the subject for Earth systems education.

Many of the questions investigated in Earth systems education relate to environmental issues and how human beings use the resources of the planet. Not only do such studies offer rich experiences with real data, and the need to consult many disciplines in search of answers, but they also provide a reason for doing science and a means of introducing the value of good stewardship of resources. Looking at the environment and how it is influenced by technology is integral to such studies.

ESE is guided by a framework of understandings that represent the goals of science teaching at all levels. These elements are also the basis of what many feel is important in global science literacy as well as much of what is traditionally considered the realm of environmental education. The scientific thinking and decision–making aspects of Earth systems education are appropriate bases for approaching environmental issues rationally.

Framework of Understandings for
Earth Systems Education

1. Earth is unique, a planet of rare beauty and great value.
2. Human activities, collective and individual, conscious and inadvertent, affect Earth systems.
3. The development of scientific thinking and technology increases our ability to understand and utilize Earth and space.
4. The Earth system is composed of the interacting subsystems of water, land, ice, air and life.
5. Earth is more than 4 billion years old, and its subsystems are continually evolving.
6. Earth is a small subsystem of a Solar system within the vast and ancient universe.
7. There are many people with careers and interests that involve study of Earth's origin, processes, and evolution.

The Sierra Club, one of the oldest environmental organizations in the world, has as its slogan, "Only one Earth". It implies that the choices individuals and nations make have a profound effect on the environment we all share, and that the opportunities to do things for and with the environment may only come once. If we deplete our nonrenewable energy resources or disrupt ecosystems with introduced species, we diminish what the Earth can offer for our future. Technology may be able to fix some of our mistakes

and prolong the time before we will have to make hard decisions, but technology is a servant, not a saviour.

Part of every student's education should include the opportunity to see the world from a systems perspective, to take steps knowing that each decision alters the path ahead just a bit. We are all on the bridge, the environment that is taking us from where we are to where we will be. If that bridge is undergirded by educational foundations in research, if the things being learned are relevant, and the resources are diverse and modern, the path will be solid and supportive of forward progress in education. If the bridge has been strengthened by science taught as a system, by technology that enhances life and learning without detriment, the journey to tomorrow can be one toward global science literacy, with peace and sustainability.

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